USGS Project Proposal

EVALUATION OF METHODS FOR ESTIMATION OF BRIDGE-PIER SCOUR FOR STREAMS WITH COARSE BED MATERIALS BASED ON OBSERVED SCOUR IN MONTANA AND OTHER MOUNTAIN STATES

PROBLEM

Channel scour around bridge piers is among the leading causes of bridge failure in the United States (Landers and Mueller, 1996). As a result, the Federal Highway Administration (FHWA) has developed methods for State highway agencies to analyze scour and estimate scour depths at existing and proposed bridges. Methods for estimating scour depth are based on empirical equations relating maximum scour depth to various hydraulic and bridge-geometry parameters. The empirical equations currently available were developed from laboratory analyses of scour, which, because of the complex nature of the scour process, may not reflect scour experience in the field. Scour depth estimates from empirical equations thus may overpredict actual scour in some instances and underpredict actual scour in other instances. To ensure that scour depth is not underestimated, some currently used equations have been adjusted to yield larger and more conservative scour-depth estimates. Estimates from those equations may indicate that more bridges are scour-critical than is actually the case and thus may lead to expensive overdesign or unecessary retrofitting.

To improve understanding of scour and develop more reliable equations for scour estimation, the FHWA and many state highway agencies have developed cooperative programs with the U.S. Geological Survey (USGS) for the collection of on-site scour data at bridges. Data from the USGS cooperative programs were analyzed by Landers and Mueller (1996) and used to evaluate 34 empirical pier-scour prediction equations in current use. Measured scour for 384 flood events at 56 bridges in 10 states were compared to calculated pier scour from each of the 34 equations. Comparisons showed that none of the prediction equations accurately estimated scour under the full range of measured conditions.

Of the 34 equations analyzed, the HEC-18 equation (currently recommended for clear-water and live-bed pier-scour analysis by the FHWA), the Froehlich equation, and the Simplified Chinese equation generally provided the most reliable estimates overall. For clear-water scour conditions, the Froehlich equation and the Simplified Chinese equation generally provided the most reliable scour estimates. These equations explicitly account for mean size of bed material and may thus provide pier-scour estimates for coarse-bed streams that are both more accurate and smaller than estimates from the HEC-18 equation. Use of the Froehlich equation or the

Simplified Chinese equation rather than the HEC-18 equation to estimate pier scour may thus result in considerable overall cost savings and more reliable designs in mountain states like Montana where coarse-bed streams are common. A cooperative study between the USGS and the Montana Department of Transportation (MDT) is proposed to evaluate the relative reliability of various scour-prediction equations for coarse-bed streams and to collect additional pier-scour data for long-term improvement of the scour-prediction process.

OBJECTIVES AND SCOPE

The overall objective of the proposed project is to improve pier-scour estimates at bridges in Montana. To this end, the proposed project has two major components.

The first component is an analysis of existing bridge-scour data in Montana and adjacent mountain states similar to the comparison study done on a national basis by Landers and Mueller (1996). The analysis would compare scour measured at bridges over coarse-bed streams to calculated scour from the Froehlich equation, Simplified Chinese equation, the HEC-18 equation, and the revised HEC-18 equation currently being evaluated by the FHWA and the USGS (Mueller, oral commun., 2000). In addition to data already included in the national study by Landers and Mueller (1996), the proposed analysis would use scour data measured since 1994 at several streams in Montana. Also, historic high-flow discharge-measurement data obtained from bridges at USGS streamflow-gaging stations on coarse-bed streams will be used wherever possible to determine pier scour for use in the analysis. The results of the analysis would be described in a USGS Water-Resources Investigations Report available for review within one year from project initiation.

The second component of the proposed project is a long-term pier-scour data collection program for bridges over coarse-bed streams throughout Montana. The goal is to obtain on-site pier-scour measurements at selected sites per year over a 5-year period. The number of measurements each year would vary, depending upon hydrologic conditions, but are expected to average between 10 and 20 per year. During high-flow years, more data would be collected, while during low-flow years less data would be collected. Limited-detail pier-scour data will be collected at each site using methods developed by the USGS (Landers and Mueller, 1996). Insofar as possible, measurements will be made on the rising limbs of the runoff hydrographs to ensure that infilling of the scour hole from sediment depostion does not occur. Sites for pier-scour data collection will be identified following a reconnaissance investigation. Approximately 20-25 sites will be identified, although data may not be collected at all sites depending upon hydrologic conditions over the course of the study. At the end of the 5-year data collection period, one additional year will be required to analyze the data. Data analysis will include a comparison, similar to that for the first study component, of measured scour with scour calculated from existing equations such as the HEC-18, Froehlich and Simplified Chinese equations. In addition, the relationship between measured scour and various hydraulic and bridge-geometry variables will be investigated to determine whether new equations for scour estimation might be more appropriate for gravel-bed streams in Montana. USGS investigators in Montana will work closely with USGS investigators in other states to ensure that scour

data collected in Montana will be included in the USGS national bridge-scour data base (Landers and others, 1996) and that data from similar streams in other states are available for the Montana analysis.

BENEFITS

Montana Department of Transportation (MDT) requires credible scientific information to evaluate scour potential at existing bridges and to economically design new bridge structures to withstand scour. Currently-used methods for scour analysis may not be economical because of a tendency to overestimate pier scour, especially for gravel-bed streams. The proposed project will provide scientific information to help determine whether currently available, alternative methods are appropriate. The proposed project also will provide for the long-term collection of on-site bridge-scour data that will enable the development of new scour prediction methods.

On a national basis, the USGS has collected and analyzed bridge-scour data for many years in cooperation with the FHWA and most states. In Montana, the USGS has worked cooperatively with the MDT on bridge-scour and related hydraulic and hydrologic studies. The proposed study builds on previous bridge-scour studies by the USGS. Thus, the USGS is the agency ideally suited to perform the proposed study.

PRODUCTS

Two USGS Water-Resources Investigations Reports will be produced. The first will describe the comparisons between measured scour and calculated scour based on existing data and will be ready for colleague review by June 30, 2001. Expected publication date for the first report is December 31, 2001. The second report will present data collected during the long-term data-collection phase of the project together with an analysis of the additional data. The second report will be ready for colleague review by June 30, 2006. Expected publication date for the second report is December 31, 2006.

In addition to the published reports, the USGS will provide measured scour data on an annual basis to the MDT. Project progress reports also will be provided on a semi-annual basis to MDT, and project meetings between USGS and MDT will be held on an as-needed basis throughout the course of the study.

FUNDING

The study will be conducted jointly by the USGS and the MDT. MDT will provide $147,900 and the USGS will provide $147,900. Field work will begin July 2000, and the project will end about December 31, 2006. Federal fiscal year (October-September) budgets are specified in table A and State fiscal year budgets (July-June) are shown in table B. Specific tasks and timelines are shown in table C. Principal investigators for the USGS study will be Charles Parrett and Stephen R. Holnbeck.

Table A. Funding for Pier Scour Study by Federal Fiscal Year.

Category	**FY 2000**	**FY 2001**	**FY 2002-05**	**FY2006**
Salaries	$6,330	$82,650	$17,220	$76,330
Travel	$0	$4,180	$4,180	0
Vehicles	$0	$3,210	$3,720	0
Report Processing	$0	$4,350	0	$4,350
Contract Services	$0	$0	$0	0
Equipment and Supplies	$870	$8,700	$870	$870
Total	$7,200	$103,090	$25,990*	$81,550

* per each of four years

Table B. Funding for Pier Scour Study by State Fiscal Year.

Category	**FY 2001**	**FY 2002-05**	**FY 2006**	**FY2007**
Salaries	$88,000	$17,220	$70,470	$6,840
Travel	$4,180	$4,180	$0	0
Vehicles	$3,210	$3,720	$0	0
Report Processing	$4,350	0	$0	$4,350
Contract Services	$0	$0	$0	0
Equipment and Supplies	$8,700	$870	$870	$870
Total	$108,440	$25,990*	$71,340	$12,060

* per each of four years

Table C. Project Tasks and Timeline by Federal Fiscal Year Quarter (Quarter 1 means Oct-Dec) .

	FY 00	**FY 2001**				**FY 2002-2005**				**FY 2006**			
Task	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Compilation of existing data	X												
Analysis of data	X	X	X	X									
Writing first report		X	X	X	X								
Reconnaissance of data-collection sites		X											
Development of data collection plan		X	X										
Collection of long-term data				X	X			X	X				
Analysis of data										X	X	X	
Writing second report											X	X	X

REFERENCES CITED

Landers, M.N., Mueller, D.S., and Martin, G.R., 1996, Bridge Scour Data Management System Users Manual, U.S. Geological Survey Open-File Report 95-574

Landers, M.N. and Mueller, D.S., 1996, Channel Scour at Bridges in the United States, Publication No. FHWA-RD-95-184, Federal Highway Administration, 128p.